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Effect of complications on mortality after coronary artery bypass grafting surgery: Evidence from New York State

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Objective: Complications are associated with increased risk of death. The objective of this study is to quantify the increased odds of dying from complications after isolated coronary artery bypass grafting surgery.

Methods: We conducted a retrospective cohort study using the New York State Coronary Artery Bypass Grafting Surgery Reporting System for all patients undergoing isolated coronary artery bypass grafting surgery in New York State who were discharged between 1997 and 1999 (51,750 patients; 2.20% mortality). We estimated the independent effect of individual postoperative complications on in-hospital mortality after controlling for patient clinical risk factors and demographics.

Results: The mortality rate for patients without complication was 0.77% versus 16.1% for patients with complications ($P < .001$). After adjusting for preoperative risk factors, transmural myocardial infarction (adjusted odds ratio, 7.90; $P < .001$), respiratory failure (adjusted odds ratio, 6.02; $P < .001$), renal failure (adjusted odds ratio, 7.15; $P < .001$), and stroke within 24 hours (adjusted odds ratio, 4.09; $P < .001$) were the most strongly associated with mortality.

Conclusions: There is a strong association between postoperative complications and in-hospital mortality. Complications after isolated coronary artery bypass grafting surgery are associated with a 1.4- to 8-fold increase in the odds of death after adjusting for severity of disease and comorbidities. This information might prove valuable to hospitals in their efforts to design quality improvement initiatives and care protocols to improve mortality after coronary artery bypass grafting surgery.

Coronary artery disease is the leading cause of death in the United States.[1] Recent evidence suggests that coronary artery bypass grafting (CABG) surgery might be the treatment of choice in patients with multivessel coronary artery disease.[2] The release of public and nonpublic CABG outcome report cards is associated with reductions in CABG mortality rates.[3-5] Even greater reductions in mortality rates might be achievable if hospitals can identify which complications are associated with the highest mortality and then focus quality improvement efforts on these complications.[6]

The purpose of this study was to estimate the increased risk of mortality in patients who have specific complications after CABG surgery. Because higher-risk patients are both more likely to have complications and to die, it is important to adequately adjust for severity of disease to quantify the contribution of complications to mortality.[7] Administrative data are not ideally suited to this type of analysis because they frequently undercode both complications[8-11] and comorbidities[12,13] and often do not accurately differentiate between complications and comorbidities.[14,15] We chose to perform this analysis using the New York State (NYS) Coronary Artery Bypass Surgery Reporting System (CSRS) database, which contains clinical data on mortality, complications, and preoperative risk factors for all patients undergoing isolated CABG surgery in NYS.[3]

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Abbreviations and Acronyms

ACC = American College of Cardiology
AHA = American Heart Association
CABG = coronary artery bypass grafting
CSRS = Coronary Artery Bypass Surgery Reporting System
NYS = New York State
OR = odds ratio

Materials and Methods

Data

This study uses data from the NYS CSRS and includes all patients undergoing isolated CABG surgery in NYS who were discharged between 1997 and 1999 (51,750 patients; 2.20% mortality). This database includes information on patient demographics, hospital and physician identifiers (encrypted), preoperative risk factors, and outcomes. These clinical data were collected prospectively at the hospital level and were then submitted to the NYS Department of Health. Audit mechanisms were in place to ensure the accuracy of the data.[16] This study was exempted from institutional review board approval because it involved the secondary use of pre-existing data.

Information on left ventricular function was missing for approximately 3% of the patients.* We constructed an imputation model[17] to predict the ejection fraction by using the STATA (STATA Corp, College Station, Tex) "impute" procedure, which is based on best-subset regression. Imputed values for patients with missing ejection fractions were calculated by using the imputation model.

Initial exploratory analyses compared the distribution of individual risk factors for patients without postoperative complications with those for patients with at least 1 complication. Continuous covariates were compared by using the *t* test, and categoric covariates were compared by using the χ^2 test.

Model Development

We first constructed a risk adjustment model to predict in-hospital mortality that included only preoperative risk factors. Bivariate analyses were performed to evaluate the association between mortality and patient preoperative risk factors. Those risk factors with a *P* value of .20 or less were considered candidate variables for inclusion in the multivariate prediction model. Forward stepwise selection ($P \leq .05$) was used to identify the risk factors that were independently associated with in-hospital mortality. The method of fractional polynomials[18] was used to determine the optimal transformation for continuous covariates. Robust variance estimators[19] were used to account for the fact that outcomes for patients treated by the same surgeon were likely to be correlated. We then estimated a second model, based on the first model, which also included postoperative complications, in addition to previously identified preoperative risk factors, as predictor variables for mortality. Model discrimination was evaluated by using the c-statistic.[20] This final model was used to estimate the independent contribution of individual postoperative complications to in-hospital mortality.

*For the purpose of this analysis, we defined an ejection fraction of zero as missing data.

All statistical tests were 2-tailed. Data management, regression analysis, and regression diagnostics were performed with STATA SE/9.1 software (STATA Corp).

Results

The study sample consisted of 57,150 patients treated by 189 surgeons at 33 hospitals. The preoperative risk factors for death of the patient groups with and without complications are compared in Table 1. Compared with patients without complications, patients who went on to sustain 1 or more complications were more likely on presentation to be in congestive heart failure, to be unstable, to be in shock, to have undergone cardiopulmonary resuscitation, or to be transferred on an emergency basis to the operating room after an unsuccessful percutaneous intervention. They were also more likely to have significant comorbidities (diabetes, hepatic failure, renal failure, and chronic obstructive pulmonary disease) and to have more severe atherosclerotic disease (previous stroke, carotid disease, aortoiliac disease, femoral-popliteal disease, and calcified aorta). They were also more likely to have poor ventricular function (left ventricular ejection fraction ≤20%) and to have had a recent myocardial infarction, previous cardiac surgery, and left main coronary artery disease.

Approximately 9% of the patients had 1 or more complications after isolated CABG surgery (Table 1). The mortality rate for patients with 1 or more complications (16.1%) was 20 times the mortality of patients with no complications (0.77%, $P < .001$). Complications that were associated with the highest mortality rates were renal failure (49.4%), sepsis (41.6%), gastrointestinal bleeding (32.6%), and respiratory failure (31.2%). After adjusting for preoperative risk factors, transmural myocardial infarction (adjusted odds ratio [OR], 7.90; $P < .001$), respiratory failure (adjusted OR, 6.02; $P < .001$), renal failure (adjusted OR, 7.15; $P < .001$), and stroke within 24 hours (adjusted OR, 4.09; $P < .001$) were most strongly associated with mortality (Table 2). The full model is shown in Appendix 1.

Discussion

We find that patients undergoing isolated CABG surgery who have 1 or more complications during the postoperative period have between a 1.4- and 8-fold increase in the odds of mortality compared with patients who do not have complications during the postoperative period. This study is the first multicenter study to examine the effect of postoperative complications on in-hospital mortality after isolated CABG surgery. Through a better understanding of the effect of individual complications on mortality, hospitals might be able to more effectively focus their quality improvement effort on reducing those complications that have the greatest effect on mortality.

In theory, a focused approach that targets specific complications through the application of evidence-based clinical

TABLE 1. Preoperative risk factors of patients with and without any postoperative complications

	No complications (n = 51,789)	Any complication (n = 5361)	*P* value
Demographics			
Age (y)	65.7	68.9	<.001
Female sex	28.2	34.3	<.001
BSA (m^2)	1.99	1.94	<.001
Hemodynamic status			
Unstable	1.14	3.58	<.001
Shock	0.35	1.92	<.001
CPR	0.15	0.75	<.001
Intravenous nitroglycerin within 24 h	19.2	27.8	<.001
CHF, this admission	11.1	22.0	<.001
CHF, previous admission	7.60	11.2	<.001
Malignant ventricular arrhythmia	2.00	3.66	<.001
Emergency transfer to OR after PCI	0.69	2.70	<.001
Comorbidities			
Diabetes	30.0	35.5	<.001
Hepatic failure	0.08	0.41	<.001
Renal failure, not on dialysis	1.10	2.33	<.001
Renal failure, on dialysis	1.54	4.68	<.001
Chronic obstructive pulmonary disease	15.4	21.2	<.001
Severity of atherosclerotic disease			
Previous stroke	6.32	11.7	<.001
Carotid disease	13.6	21.9	<.001
Aortoiliac disease	4.64	8.64	<.001
Femoral-popliteal disease	8.42	14.1	<.001
Calcified aorta	5.40	11.6	<.001
Ventricular function			
Ejection fraction ≤20	1.63	3.32	<.001
Previous MI, <6 h	0.73	2.35	<.001
Previous MI, 6-23 h	0.77	1.96	<.001
Previous MI, 1-7 d	14.2	15.15	.052
Previous MI, >7 d	40.9	42.9	.004
Previous cardiac surgery			
1	5.39	8.38	<.001
≥2	0.44	0.65	.027
Extent of coronary artery disease			
Left main, 70%-89%	8.92	10.2	.002
Left main, >89%	5.57	7.78	<.001

All values are percentages unless otherwise stated. Continuous variables were compared by using 2-sample *t* tests, and categoric variables were compared by using the χ^2 test. *BSA*, Body surface area; *CPR*, cardiopulmonary resuscitation; *CHF*, congestive heart failure; *OR*, operating room; *PCI*, percutaneous coronary intervention; *MI*, myocardial infarction.

practice guidelines might have a significant effect on complication rates and mortality. Implementation of the American College of Cardiology (ACC)/American Heart Association (AHA) Practice Guidelines[21] might help to reduce the incidence of complications and their associated mortality. Some of the practice guidelines issued by the ACC/AHA include (1) the administration of blood cardioplegia in patients undergoing urgent/emergency CABG surgery or in patients with severe left ventricular dysfunction to improve myocardial protection, (2) the prophylactic use of an intra-aortic balloon pump in patients with severe left ventricular dysfunction as an adjunct to myocardial protection, (3) the preoperative administration of antibiotics to reduce the risk of surgical infection, and (4) the postoperative use of antiplatelet therapy and statin therapy to reduce the risk of saphenous vein graft closure. Of the 6 recommendations issued by the ACC/AHA, however, only 3 are class I recommendations† supported by strong evidence.‡ The nar-

†"Conditions for which there is evidence and/or general agreement that a given procedure or treatment is beneficial, useful, and effective."[21]

‡"Data derived from multiple randomized clinical trials or meta-analyses."[21]

TABLE 2. Association between mortality and complications before and after adjusting for preoperative clinical risk factors

			Bivariate analysis		Multivariate analysis	
	No.	Dead, %	Unadjusted OR	*P* value	Adjusted OR	*P* value
Cardiac						
Transmural myocardial infarction	436	18.6	10.7	<.001	7.90	<.001
Pulmonary						
Respiratory failure	2311	26.9	31.2	<.001	6.02	<.001
Renal						
Renal failure, dialysis	545	49.4	54.7	<.001	7.15	<.001
Neurological						
Stroke, within 24 h	502	19.9	11.9	<.001	4.09	<.001
Stroke, >24 h	642	17.3	10.1	<.001	3.58	<.001
Bleeding						
Bleeding requiring reoperation	1252	10.2	5.51	<.001	2.60	<.001
Gastrointestinal						
GI bleeding	512	32.6	24.6	<.001	3.49	<.001
Infection						
Deep sternal wound infection	566	12.7	6.79	<.001	1.39	.126
Sepsis	514	41.6	37.9	<.001	2.74	<.001

The multivariate logistic regression model is adjusted for the following covariates: age, sex, body surface area, hemodynamic status (unstable, shock, cardiopulmonary resuscitation, intravenous nitroglycerin within 24 hours, congestive heart failure on this admission, history of congestive heart failure on a previous admission, malignant ventricular arrhythmia, and emergency transfer to operating room after percutaneous intervention), comorbidities (diabetes, hepatic failure, renal failure not on dialysis, renal failure on dialysis, and chronic obstructive pulmonary disease), severity of atherosclerotic disease (previous stroke, carotid disease, aortoiliac disease, femoral-popliteal disease, and calcified aorta), ventricular function (ejection fraction and previous myocardial infarction), previous cardiac surgery, and extent of coronary artery disease. C-statistic = 0.917. *OR*, Odds ratio; *GI*, gastrointestinal.

row scope of these practice guidelines, however, highlights the critical limitations of the evidence base linking processes of care to outcomes after cardiac surgery and reinforces the need to further expand the list of evidence-based best practices.

Recent studies have estimated the effect of complications for Medicare patients undergoing general and orthopedic surgery[7] and for Veterans Administration patients undergoing major vascular, general, and orthopedic surgery.[6] Using a case-control design, Silber and colleagues[7] found that Medicare patients who experienced a postoperative complication had 3.4-fold increased risk of mortality within 60 days of admission compared with patients without a complication. Using data from the National Surgical Quality Improvement Program database, Khuri and associates[6] found that Veterans Administration patients undergoing major noncardiac surgery who experienced a postoperative complication had their median survival reduced by 69%. A third study, based on a single center, reported that cardiac surgery patients who had complications were more likely to die or have a prolonged length of stay.[22]

In contrast to these other studies, we examined a relatively homogeneous population undergoing only isolated CABG surgery, as opposed to modeling the effect of complications on mortality for several diverse surgical populations using a single model. By including several unrelated procedures within a single regression model, these other studies might not adequately control for preoperative risk factors because it is unlikely that the effect of these risk factors on mortality will be the same across different surgical procedures. For example, it is unlikely that a history of myocardial infarction is associated with the same risk of death in a patient undergoing a carotid endarterectomy compared with a patient undergoing an open abdominal aortic aneurysm repair.[23]

In contrast to Silber and colleagues,[7] we were unable to quantify the effect of the "first" postoperative complication on outcome because we did not have access to patient charts and the CSRS data set does not date postoperative complications. It is likely that some of the complications included in our analysis might, in some cases, occur "downstream" of the first complication. For example, renal failure could be a first complication when it occurs because of a low cardiac output after terminating cardiopulmonary bypass or it might be a "delayed" complication when it occurs in the setting of multisystem organ failure in a patient with pneumonia and sepsis. However, some of the complications, such as transmural myocardial infarction, stroke, deep sternal wound infection, and bleeding requiring reoperation, are likely to represent first complications as opposed to delayed complications. From the standpoint of quality improvement, it is more useful to measure the effect of first complications on mortality because efforts to prevent complications would be ideally targeted at first complications, as opposed to targeting delayed complications that occur as a result of a first complication.

Our results should be interpreted with caution, because this study has several important limitations. First, the data on complications might not be completely accurate. Previous audits by the NYS Department of Health have found that complications are undercoded in the CSRS.[§] Second, it was necessary to impute the values for ejection fraction in 3% of the cases. Third, although we believe that our analysis controlled for all potentially relevant confounders, it is possible that the absence of unmeasured variables might have biased our findings. Finally, this study is based on data from NYS and might not be generalizable to other regions of the United States.

Conclusions

In summary, we find that complications after isolated CABG surgery are associated with a 1.4- to 8-fold increase in the odds of death after adjusting for severity of disease and comorbidities. This information might prove valuable to hospitals in their efforts to design quality improvement initiatives and care protocols to improve mortality after CABG surgery. Further studies are necessary to develop a more comprehensive set of evidence-based guidelines aimed at reducing complication rates for CABG surgery and to evaluate the benefit of implementing these guidelines once they have been developed.

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§Based on personal communication with Dr. Michael Racz, NYS Department of Health (2006).

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Appendix 1. Full model

	Odds ratio	P value
Preoperative risk factors		
Demographics		
Age	1.09	<.001
Female sex	1.40	<.001
BSA^2	0.128	<.001
BSA^2 ln(BSA)	5.25	<.001
Hemodynamic status		
Unstable	1.47	.041
Shock	3.25	<.001
CPR	4.34	<.001
Intravenous nitroglycerin within 24 h	1.34	<.001
CHF, this admission	1.22	.028
CHF, previous admission	1.32	.003
Malignant ventricular arrhythmia	1.52	.009
Emergency transfer to OR after PCI	1.19	.532
Comorbidities		
Diabetes	1.26	.002
Hepatic failure	2.36	.141
Renal failure, not on dialysis	1.12	.556
Renal failure, on dialysis	4.32	<.001
Chronic obstructive pulmonary disease	1.31	.002
Severity of atherosclerotic disease		
Previous stroke	1.20	.092
Carotid disease	1.21	.011
Aortoiliac disease	1.70	<.001
Femoral-popliteal disease	1.17	.093
Calcified aorta	1.42	.001
Ventricular function		
Ejection fraction	0.980	<.001
Previous MI, <6 h	2.25	.001
Previous MI, 6-23 h	1.12	.691
Previous MI, 1-7 d	1.45	.001
Previous MI, >7 d	1.22	.023
Previous cardiac surgery		
1	2.32	<.001
≥2	4.51	<.001
Extent of coronary artery disease		
Left main, 70%-89%	1.20	.075
Left main, >89%	1.40	.007
Postoperative complications		
Transmural myocardial infarction	7.90	<.001
Respiratory failure	6.02	<.001
Renal failure, dialysis	7.15	<.001
Stroke, within 24 h	4.09	<.001
Stroke, >24 h	3.58	<.001
Bleeding requiring reoperation	2.60	<.001
Gastrointestinal bleeding	3.49	<.001
Deep sternal wound infection	1.39	.126
Sepsis	2.74	<.001

C-statistic = 0.917. *OR*, Odds ratio; *BSA*, body surface area; *CPR*, cardiopulmonary resuscitation; *CHF*, congestive heart failure; *OR*, operating room; *PCI*, percutaneous coronary intervention; *MI*, myocardial infarction.